PB-230 339

REMOTE SENSING REPORT, GALVESTON BAY, HOUSTON SHIP CHANNEL, TRINITY BAY, HOUSTON, TEXAS FOR FEBRUARY 1972

National Field Investigations Center-Denver
Denver, Colorado

April 1972

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ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF ENFORCEMENT

PB 230 339

REMOTE SENSING REPORT

GALVESTON BAY, HOUSTON SHIP CHANNEL, TRINITY BAY

HOUSTON, TEXAS

[redacted]

NATIONAL FIELD INVESTIGATIONS CENTER-DENVER

DENVER, COLORADO

AND

REGION VI DALLAS, TEXAS

APRIL 1972

CLEAN WATER

PB 230 339

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GALVESTON BAY

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REMOTE SENSING REPORT

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INTRODUCTION

An aerial remote sensing program, requested by EPA Region VI, is being conducted approximately twice every month from February 1972 to January 1973. The report contained herein establishes the intelligence obtained from the first mission. The areas covered during this mission are given as follows:

a) Houston Ship Channel - from the Turning Basin, at Buffalo Bayou, to Morgan Point;

b) Galveston Bay - from Morgan Point along the Houston Ship Channel to the Gulf of Mexico; and

c) Trinity Bay - in the vicinity of the Houston Lighting and Power Company cooling water canal discharge.

MISSION PURPOSE

The expressed purpose of this aerial reconnaissance program was to fulfill the following objectives:

a) provide industrial outfall trend data;

b) provide data regarding the presence and the sources of oil pollution especially in the Houston Ship Channel; and

c) provide data regarding the presence of thermal pollution in Trinity Bay.

BACKGROUND

Three previous missions were flown over the Houston Ship Channel and Galveston Bay during July 1971. Nearly all of the industrial discharges into the Channel were documented during that effort.

CHRONOLOGICAL DATA

This mission was conducted on 18 February 1972. The time over target was 1100 to 1230 hours CST. The flight altitudes were maintained at 3,400 feet and 2,250 feet MSL (above-mean-sea level).

AIRCRAFT SENSOR DATA

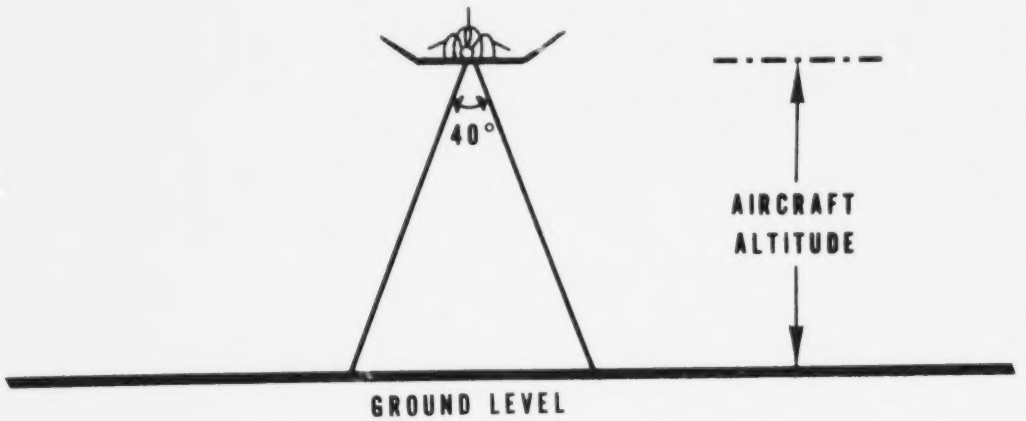
The reconnaissance data were recorded aboard two high performance aircraft. Each aircraft contained three framing cameras and an Infrared Line Scanner (IRLS). All cameras were mounted in the tri-vertical array, i.e., mounted in their respective vertical positions coincident with the nadir of the aircraft. Each of the cameras was uploaded with different film/optical filter combinations. They were capable of recording the presence of optical energy within the following bands of the optical spectrum:

(a) Near ultraviolet, resulting in a 4.5" X 4.5" negative - Kodak 2403 recording film with a Wratten 47A gelatin optical filter;

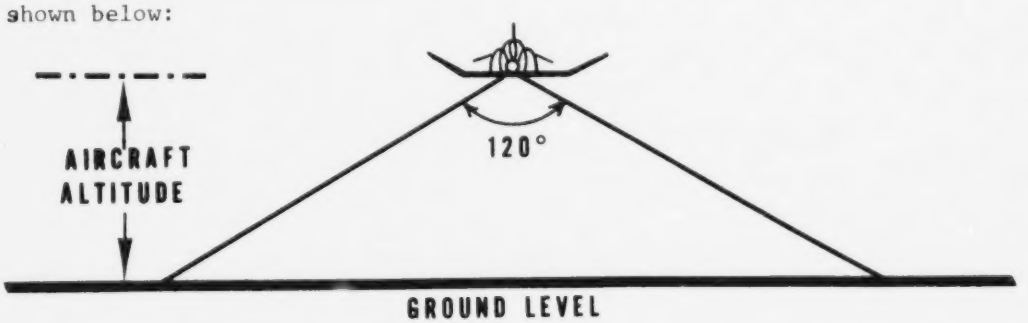
(b) Visible region of the optical spectrum, resulting in a true color 4.5" X 4.5" positive aerographic ektachrome transparency - Kodak SØ-397 aerographic ektachrome film with a Wratten HF-3/HF-5 optical filter combination; and

(c) Near infrared region of the optical spectrum which was overlapped with a portion of the visible spectrum (red, orange), resulting in an aerographic ektachrome 4.5" X 4.5" false color (rendition) transparency - Kodak 2443 aerographic film with a Wratten 16 gelatin optical filter.

This viewing angle of each camera was 41° about the aircraft's nadir as shown below:



The IRLS is a cryogenic device (optical and electronic) capable of detecting passive electromagnetic energy resulting from target thermal emissions in the infrared band from 8 to 14 microns (1 micron=10^{-6} meters). It has a cross-track scan angle of 120° about the aircraft's nadir, as shown below:



The first two photographic media discussed above were chosen expressly for their capability of recording the presence of oil/grease. Oils are known to be fluorescent compounds (a fluorescent compound absorbs incident radiation and re-emits energy at a longer wavelength than that of the incident. If the re-emitted energy wavelength is equal to that of the incident radiation, this is called resonance or resonant fluorescence.) and have a characteristic wavelength, in the near ultraviolet region, of approximately 0.38 microns. The black-and-white film is capable of recording this fluorescent radiation in the near ultraviolet band. The true-color transparencies are used to provide correct color rendition(s) of targets in question and are extensively used in location and target identification work.

The false color infrared film was used for the documentation of effluent dispersion patterns in water, which was due to the wider color separation in the false color rendition. It is also used for the detection and identification of shrouded or masked (due to color likeness or foliage) waterways. This film provides information for the documentation of relative turbidity/DO levels in addition to biological growth detection and identification.

DESCRIPTION OF DATA REDUCTIONS

The results of the interpretation of the airborne reconnaissance data are presented with respect to each target area (items a,b, and c of the Introduction) in the following paragraphs:

I. Houston Ship Channel

1. Buffalo Bayou - A great part of the dark yellowish-brown substance seen on the surface of the Ship Channel water was coming from Buffalo Bayou upstream of the Turning Basin.

2. A reddish-brown substance was being discharged from the Armour Fertilizer Company complex. The outfall was located on the southern bank of the Ship Channel approximately 1,600 feet downstream of the mouth of the Turning Basin. The discharge plume extended downstream, along the Channel's bank, 125 feet before dispersing.

3. Bray's Bayou - The water, which was slowly flowing into the Ship Channel from Bray's Bayou, was extremely dark in color exhibiting septic tendencies. The mixing of these two waters was quite slow to the point of well defined boundaries existing between them. This is shown in Figure 1.

4. A yellowish-gray substance was being discharged at a point in the waterway commonly known as Harrisburg Bend adjacent to the southernmost tip of Brady Island. The discharge point appeared to be submerged. The substance could be traced 223 feet out into the waterway before dispersing.

5. A black substance was being discharged into the Harrisburg Bend waterway from a cove or indentation located on the southern tip of Brady Island, as shown in Figure 1. This cove was 160 feet wide at its mouth and extends 208 feet inland from the loading dock. The plume extended 97 feet into the above mentioned water-

SCALE IS APPROXIMATELY 1:7,000.

Figure 1 Brady Island Area

way from the same loading dock. The discharge was definitely not oil.

6. A small oil slick was harboring adjacent to a ship docked at Building 31 within the Navigational District Complex. The surface area of this slick was 14,700 $feet^2$ (140' X 105').
7. An outfall was located on the Ship Channel's southern bank, within the Charter International Company's complex. It was 1,600 feet upstream from their main dock (adjacent to Manchester Terminal). The content of the discharge was, for the most part, water whose temperature was warmer than the ambient receiving water temperature. A small quanitity of oil was also being discharged from this respective point. The resulting slick measured 173 feet at its widest point and 835 feet downstream from the outfall position. The slick was extremely thin.
8. Small, scattered oil slicks were observed in the Channel water adjacent to the Manchester Terminal Corporation's docking area located immediately upstream from Simms Bayou. The slicks were extremely thin. The source of the oil could not be established.
9. The water from Simms Bayou, which was flowing into the Ship Channel, was extremely dark indicating septic tendencies.
10. At the time of flight, the Simms Bayou Turning Basin contained several small oil slicks. They covered approximately one-fourth the total area of the Turning Basin. The source of the oil could not be established.

11. Traces of oil were being discharged from two separate locations along the southern shore bank of the Channel. This area was within the Atlantic Richfield Refining Company complex. The discharge positions were 1,280 feet and 2,250 feet respectively downstream from the crown of Simms Bayou Turning Basin. The first outfall appeared to be submerged and resulted in a small oil slick that measured 118 feet by 14 feet. The second outfall was positioned at the Channel's surface. The width of the outfall was 27 feet. This position effected an extremely thin oil slick that measured 540 feet long and 42 feet at its widest point.

    Three known outfall positions, 1,750 feet, 2,400 feet and 3,200 feet, respectively, downstream from Simms Bayou Turning Basin, were not discharging at the time of flight. The latter connects two holding ponds to the Ship Channel waters. The ponds contained small oil slicks, the largest being 750 $feet^2$.

12. A turbid substance was being discharged, at the time of flight, from a small waterway that entered the Ship Channel on its northern bank approximately 1,695 feet upstream from the Texaco slip. The source and the chemical nature of the discharge could not be determined. The complexes of Velsicol Chemical Corporation and the General American Tank Storage Terminal Company are adjacent to this respective waterway.

13. Houston Lighting and Power Company's outfall was discharging water at the time of flight. The water was not warmer than the ambient temperature of the Vince Bayou waters. The outfall was located 665 feet upstream, on the western bank of Vince Bayou, from the southern bank of the Ship Channel.

14. The U.S. Plywood - Champion Paper Company's submerged outfall was discharging a reddish-brown substance at the time of flight. The outfall was located 1,355 feet downstream from the eastern crown of Vince Bayou and 58 feet into the water from the Channel's southern bank. The above-mentioned substance floated on the surface of the Ship Channel waters and could be easily traced downstream for more than a mile before nearly complete dispersion had occurred.

15. An oil spill was in progress at the Crown Central Petroleum Corporation complex. Oil, mixed with a black substance (probably coke), was being discharged from a chute measuring 10 feet wide and 112 feet in length. The chute was located 87 feet downstream from Crown Central's slip on the Channel's southern shore. There was a floating type skimmer anchored to the bank around this outfall. It was containing only a small portion of the total substance discharged.

    Oil was also entering the Ship Channel from Crown Central's slip. The resulting oil slick could be traced 435 feet downstream from the above mentioned slip and extended 210 feet into the Channel from the southern shore.

    Another floating skimmer was located 1,140 feet downstream from Crown Central's slip. It was within their complex. This apparatus was containing nearly all of a yellowish-brown substance. The surface area of the contained substance was approximately 7,580 square feet.

16. A small oil slick was observed harboring between the Channel's southern shore and a ship docked at the complex of Horton & Horton, Incorporated. The ship was washing out at the time of flight, which produced the slick.

17. Numerous small thin oil slicks were observed on the waters of Cottonpatch Bayou. They covered nearly one-half of that water's surface. A portion of the oil was seen emanating from a barge docked near the apex of the Bayou.

18. An oil slick was observed extending from the Ship Channel's northern bank, adjacent to the western edge of the mouth of Hunting Bayou, across the Channel waters to the southern bank. It then propagated downstream for approximately 1,170 feet.

19. A total of three separate outfalls were observed discharging into the Houston Ship Channel from the Olin Corporation facility. The locations of the outflow positions are described as follows:

Note: The point of reference will be the dock that extends out into the Channel and bisects the large building that lies parallel to the southern bank.

a) The position furthest upstream was 1,110 feet from the western edge of the reference point. It was discharging a yellowish-brown substance whose chemical nature was unknown at the time of flight. The elevation of the outfall appeared to be immediately below the water's surface.

b) The second outfall position was located 563 feet upstream

from the above-mentioned reference point. It was completely submerged discharging a yellowish-gray substance whose chemical nature was not known at the time of flight.

c) The third outfall position, the largest, was located in a shoreline indentation 955 feet downstream from the eastern side of the reference point. It was discharging a yellowish substance under considerable pressure. The plume was 28 feet wide at its source and extended 264 feet out into the Channel before dispersing.

20. Three outfalls located 1,190, 1,870 and 2,395 feet, respectively, upstream in a small waterway that separates the Armco Steel Corporation and the Hess Oil and Chemical Corporation facilities, were observed discharging a yellowish-brown substance of unknown chemical constituency. The source(s) of the discharged substance could not be definitely established but adjacent to each discharge point or location was a holding pond, whose contents were of an identical color, within the Hess Oil facility. Likewise, Armco Steel Corporation had a holding pond, nearly rectangular in shape, whose contents displayed the same color.

21. A small waterway, projecting southward from the Channel, was located between the facilities of Phosphate Chemical Corporation and Phillips Chemical Corporation. An overhead pipeline passed over this waterway near its mouth and connected Phosphate Chemical's complex to Adams Terminal. A yellowish-brown substance was

present in the lower reaches of this waterway at the time of flight. The density of the substance greatly increased at a point adjacent to Phillips Chemical's holding pond. The actual source of the turbid substance could not be determined.

22. There were numerous small oil slicks that extended across the Ship Channel from Armco Steel Corporation into Adams Terminal.

23. A yellowish-orange substance was being discharged from a submerged outfall about 122 feet into the water of the Adams Terminal Basin from its apex or southernmost point. Nearly all of the discharged substance remained in this area. A small amount of the discharge did follow the Basin's shoreline downstream out into the Ship Channel waters where final dispersal was achieved. One of the constituents of this discharge, in small proportions, was oil.

24. A dark red substance was being discharged from an outfall located within the Armco Steel Corporation facility. The outfall position was established as being in an indentation in the Ship Channel's northern bank directly opposite the easternmost edge or point of the Adams Terminal Basin. The resultant plume was 140 feet wide and extended 313 feet out into the Channel waters from the northern bank. The plume was dispersing rather quickly.

25. There were numerous small oil slicks in the rather small waterway located on the eastern boundary of the Phillips Chemical Corporation facility (east of Adams Terminal and across the

Ship Channel south from the Todd Ship Yard). There were two barges and a ship docked in this area at the time of flight. The ship was in the process of washing out and did appear to be the source of one of the aforementioned oil slicks.

26. There was a small ditch, which served as a discharge medium for a quite turbid substance, located on the western boundary of the Ethyl Corporation facility. The turbid substance entered the Ship Channel waters and traveled downstream where it mixed with the turbid waters entering the Channel from Greens Bayou. This ditch was adjacent to one of the holding ponds within the complex of the aforementioned corporation. There was no water observed in the ditch upstream of this holding pond. Seepage or actual discharge of the liquid within the pond to the ditch was suspected.

27. A small waterway (large ditch) was discharging a yellowish-brown substance into Greens Bayou at a point immediately upstream of the Navigational District docking facility. This waterway's path was parallel to a quite large holding pond, located between Greens Bayou and the San Jacinto Ordnance Depot. This area is within the facilities of Southland Paper Company. Although a direct water path could not be positively established between the pond and the ditch, the color of the substances in the pond and in the ditch was identical.

28. A large discharge was observed coming from the pond complex belonging to the Ethyl Corporation. One portion of the discharge was an extremely dark brown substance originating from the holding pond adjacent to the southern bank of the Ship Channel. Another holding pond was discharging an orange-brown substance into a ditch leading to the Channel. The third outfall, a yellowish-brown substance, had come from an industrial area within the above-mentioned facility. The temperature of the discharge was warmer than the ambient temperature of the receiving waters of the Channel. The chemical nature of these discharges was unknown at the time of flight.

Downstream of the above mentioned industrial area, the presence of two large holding ponds was recorded. They were within the Ethyl Corporation facility. At the time of flight, approximately one-half of the total surface area of these ponds was covered with liquid. There was a drainage ditch observed that connected the two ponds directly to the Ship Channel. This ditch was in such a position that when the liquid level in the ponds achieved a certain depth the excess would pass directly to the Channel waters. The chemical constituency of the substance retained by the ponds was not known at the time of flight.

Along the eastern boundary of Ethyl Corporation's industrial area were several small ponds or low areas in the terrain. These ponds contained a dark brownish-gray substance. At the

time of flight, the substance was passing from the above-mentioned ponds into a ditch which provided a direct path for the same to the Ship Channel waters. The chemical constituency of the drainage was unknown at the time of flight.

29. The Southland Paper Company outfall was discharging an extremely dark brown (nearly black) substance into the Ship Channel waters. The location of the discharge was established as a submerged outfall on a peninsular projection measuring 2,420 feet downstream, on the Channel's northern bank, from the peninsular tip on the eastern bank of Greens Bayou. The plume could be easily traced downstream from the outfall for more than a mile. The Chemical nature of the discharge had been previously established as a sulfide liquor, in accordance with information provided by the EPA Galveston Bay Field Station.

30. An outfall, located at the Channel water's surface, was discharging a dark grayish-brown liquid at the time of flight. The outfall originated from a pond network adjacent to the Ship Channel's southern bank within the Tenneco Chemical Company complex. It was positioned 280 feet downstream from the dock gangway. The resultant plume could be traced downstream for approximately 1,570 feet before finally dispersing.

31. There was an outfall present, at the time of flight, from the westernmost pond on the Boggy Bayou Peninsula (the eastern pond was dry). This pond contained a dark grayish-brown substance which was being discharged into the Ship Channel from

a ditch 1,410 feet upstream, on the southern bank, from the tip of the above-mentioned peninsula. The plume was localized with virtually no dispersion evident.

32. A ship was seen washing out while being tied to the Shell Oil Company dock in the Boggy Bayou Basin. The effluent liquid appeared to contain suds.

33. There were two definite outfalls that were discharging from the Shell Oil Company complex. They were located 328 and 805 feet, respectively, downstream from Shell's docking area. The former outfall was discharging a small volume of a reddish-brown liquid. The latter outfall was that of Shell's sewage treatment facility. This respective discharge was producing no discoloration in the Ship Channel waters.

There was an oil slick clinging along the Channel's southern bank adjacent to the Shell facility. It began 175 feet upstream from the sewage treatment outfall and extended downstream approximately 2,300 feet. The average width of the slick was 170 feet. The source of the oil could not be definitely established.

The trickling filter within Shell's sewage treatment facility had no evidence of surface zoogleal growth. The growth is usually required for the filter to perform efficiently.

Shell's biological pond, located adjacent to the southern bank of the Channel and the western bank of Patrick Bayou, contained

a small amount of algal growth on the water's surface and along the pond's eastern boundary.

34. Two outfalls and three holding ponds, within the Diamond Shamrock Company facility, were seen discharging at the time of flight. The outfalls were located approximately 2,400 feet and 3,250 feet, respectively, upstream from a 90° bend in Patrick Bayou. They were discharging a dark grayish-brown liquid substance, of unknown chemical constituency, into the Bayou. The resultant plumes could be traced downstream to the Ship Channel waters. The temperature of the discharged liquid increased the water temperature of Patrick Bayou, making the latter somewhat warmer than the ambient Channel water temperature.

The three above-mentioned ponds were located immediately to the east of the 90° bend in Patrick Bayou, extending downstream to its confluence with the Ship Channel. The outfall points of these ponds were 347, 932 and 1,792 feet, respectively, downstream from the aforementioned bend. The first outfall (from the bend) was discharging a yellowish-brown substance and the second/third were discharging a dark brown liquid substance (nearly black in color) into the waters of Patrick Bayou. The resultant plumes were dispersing quite slowly but could be traced to the Ship Channel. The temperature of the Bayou waters in this area was somewhat warmer than the ambient temperature of the Ship Channel waters. The chemical nature of the above-mentioned outfalls was unknown at the time of flight.

A discharge was entering the Ship Channel waters from the Diamond Shamrock Company complex. It entered from a ditch that was traced directly south of the Channel's southern bank for 1,870 feet, where it made a clockwise 90° bend to the west, entering an industrial area. There were two weirs in this ditch that were retaining a foamy matter. The waste water in this conduit carried a yellowish-brown substance directly to the Channel waters, achieving rapid dispersion. At a point approximately 1,050 feet upstream in the ditch, on the western bank, there appeared a dark yellow substance nearly in a solid state. It was slowly being carried away by the current in the ditch. The chemical constituency of these effluents was unknown at the time of flight.

35. An outfall was located downstream 1,430 feet from the peninsular tip of Patrick Bayou, on the Ship Channel's southern bank, and 2,080 feet upstream from the mouth of Tucker Bayou. This outfall was discharging an extremely dark brown (nearly black) substance into the Channel waters. The discharge was being carried by a pipe, four feet in diameter, which was positioned immediately above the water's surface. The resultant plume extended out into the Channel 45 feet from the end of the pipe and measured 28 feet at its widest point. This effluent appeared to disperse quickly. This position was established to be the main outfall of the Rohm & Haas Company.

36. There was an oil slick located mid-Channel coincident with the peninsula tip of Patrick Bayou. The overall length of the slick was 1,730 feet. Its width was measured to be 210 feet at the widest point. The source of the oil slick could not be established.

37. A brownish-gray liquid substance was following the western bank of Tucker Bayou and subsequently flowed into the Ship Channel. The source and the chemical nature of this liquid could not be established due to the lack of imagery in this area.

38. An oil slick was observed mid-Channel approximately two nautical miles downstream from the Baytown underpass. This slick was 1,870 feet long and 175 feet wide (at the widest point). The source of the oil could not be established due to the remote location of the slick. The type of oil in the slick was a processed or refined oil as opposed to a crude oil.

II. Galveston Bay

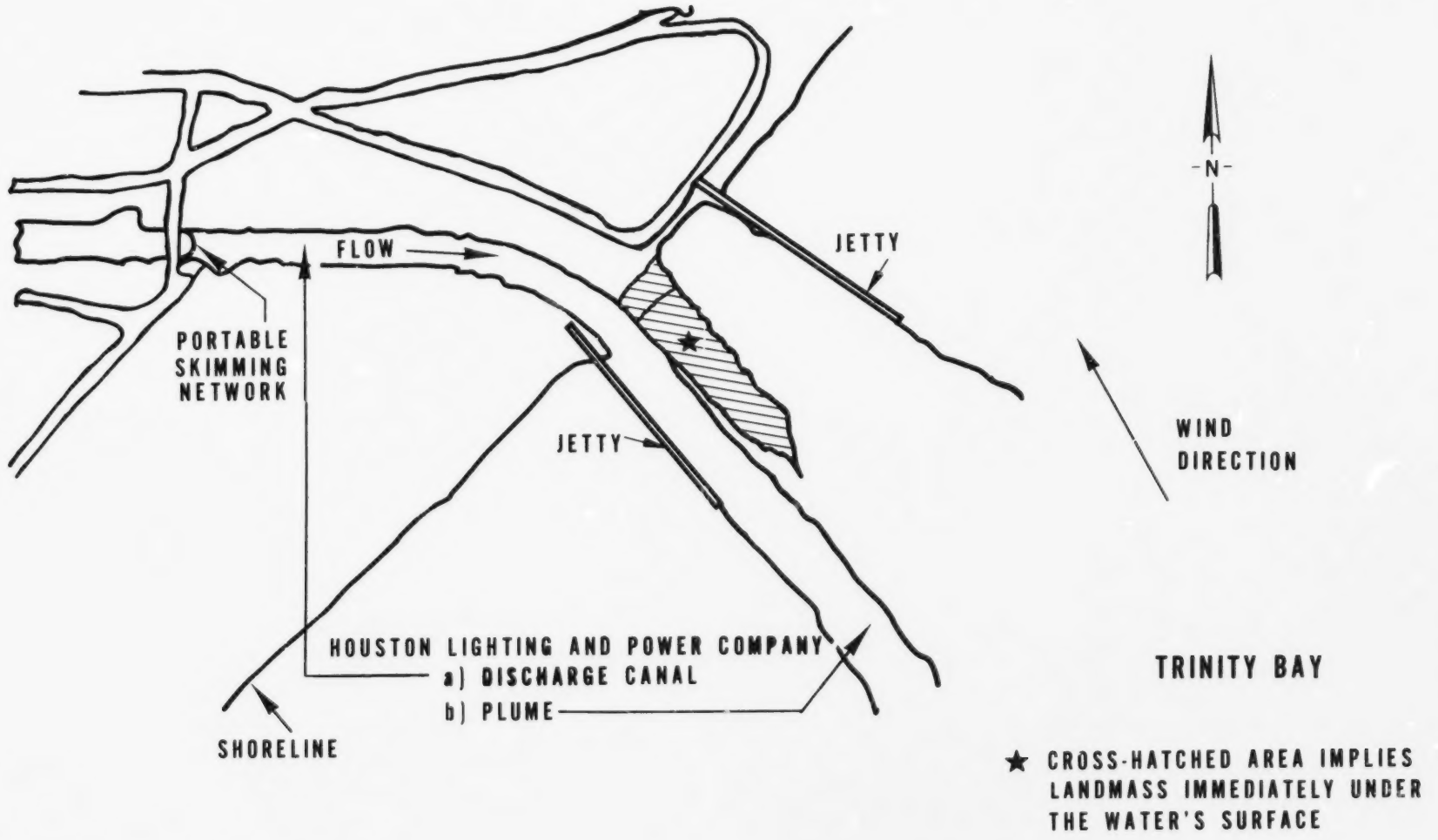
1. A scattered, discontinuous oil slick was observed beginning at a point approximately six nautical miles into Galveston Bay from Morgan Point. It propagated in a southeasterly direction, further into the Bay, along the Houston Ship Channel for approximately 12.5 nautical miles, from the aforementioned point, before significant dispersion was taking place. The

type of oil comprising the overall slick was a crude oil and not a refined oil. The source of the oil could not be established as a result of these flights.

2. An area cover (photographic) was carried out along the Houston Ship Channel in Galveston Bay from Morgan Point to the Gulf of Mexico just beyond the jetties. The water in this area was quite turbid. The Bay floor could not be seen in the imagery to depths as shallow as one foot below the water's surface. The water in the area of Atkinson Island, in the upper regions of Galveston Bay, was extremely turbid. At the time of flight there was a moderate wind blowing from the southeast. This was causing an up-welling of the bottom which contributed to the excessive turbidity. Also in this area, traces of algae were detected through photographic exposure of the presence of chlorophyll. The contour lines in the water indicating the algae growth conform, for the most part, to the upwelling contour lines. The algae population densities were small.

III. Trinity Bay

The area in the vicinity of the Houston Lighting and Power Company's cooling water discharge canal was covered photographically and with the Infrared Line Scanner. The water being discharged from the above-mentioned location was a relatively dark grayish-green color. The resultant plume shape is shown in Figure 2. This figure was derived from the respective



SCALE IS APPROXIMATELY 1:5,000.

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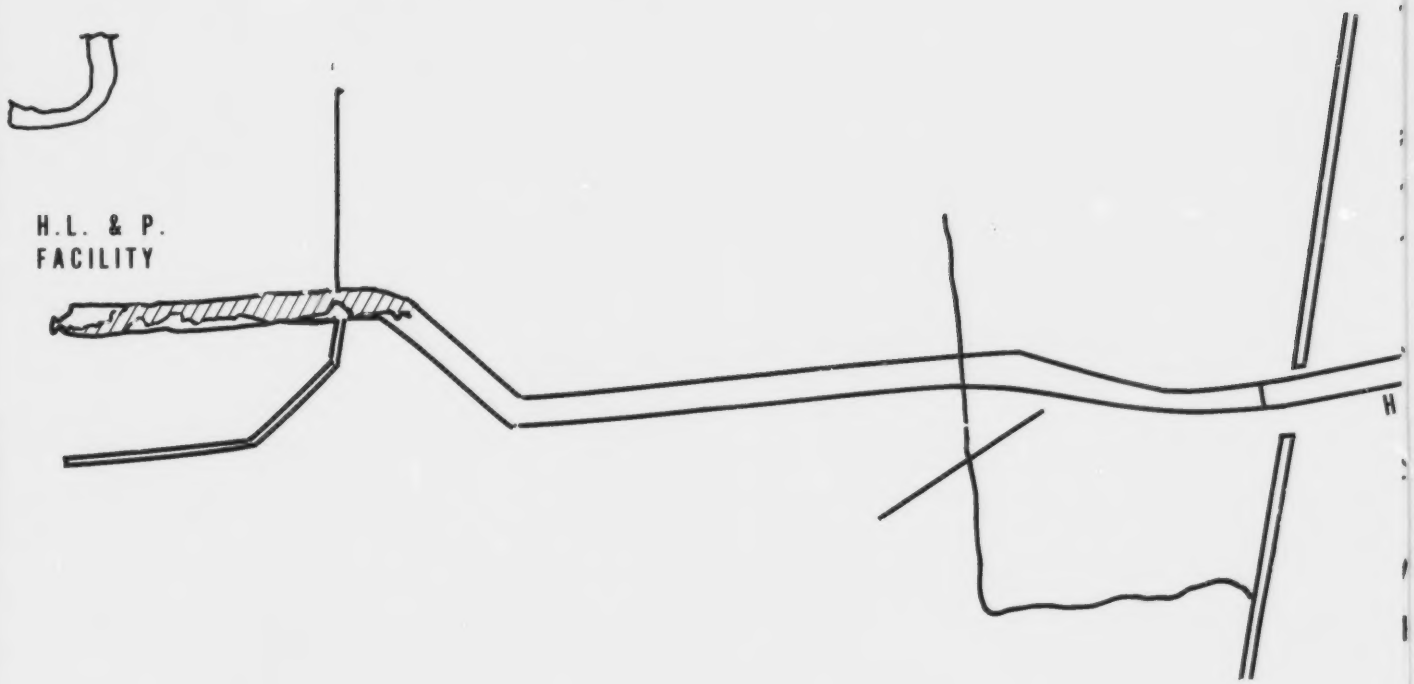
Figure 2 Optical Imagery of H.L. & P. Canal

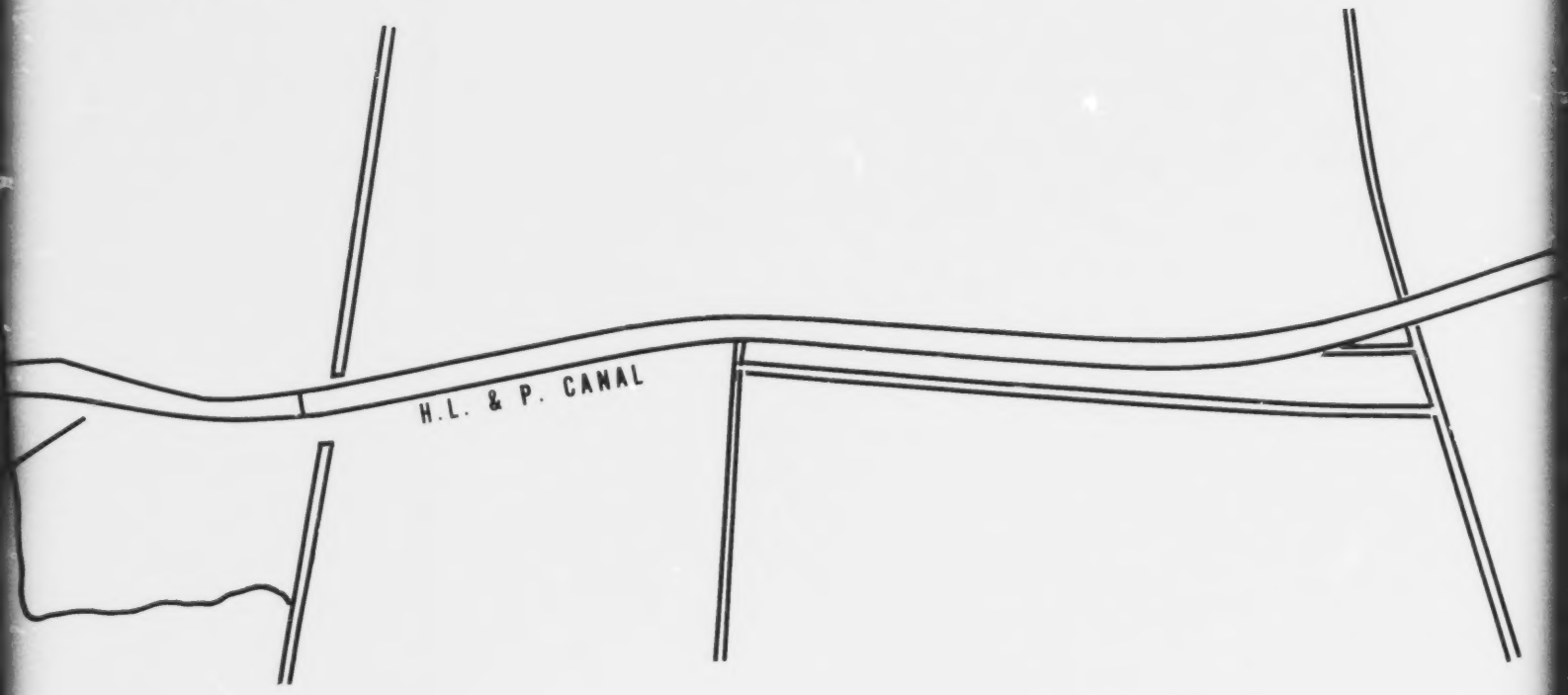
photographic imagery. The shape of the discharge plume and its dispersion traits, as derived from the thermal data (IRLS), is shown in Figure 3. It is easily seen that the plume entered Trinity Bay and drifted to the northeast. The sharp boundary, on the plume's southeastern side, was due to the wind present at the time of flight. The entire Houston Lighting and Power Company discharge canal is sketched in Figure 3. As indicated by the crosshatched areas in the composite figure, the warmer water appeared at the canal's surface (waterline) over only a fraction of the total surface area. (Only temperature variations at the water's surface are recorded by the IRLS. Water is opaque to this band within the intermediate infrared spectrum. The spectral reflectance or radiance of water is determined entirely by its surface which has been established as 0.01 cm. There is a negligible difference between the radiance characteristics of fresh and salt water in the applicable portion of the intermediate infrared spectrum which is 8 to 14 microns.) The reason for the warmer water not remaining on the surface, as indicated by the non-crosshatched area, was most probably the following:

The warmer water contained a constituent, likely in a dissolved state, that rendered the overall substance's specific gravity greater than that of the ambient salt water. This would cause the former to sink forming a density layer current along the bottom of the canal. Then, approximately 800 feet upstream in the canal from the trap flume, the warmer water began to surface. As it went over the flume with the cooler water, a complete thorough mixing was achieved as indicated by the crosshatched area adjacent to the shoreline in the canal.

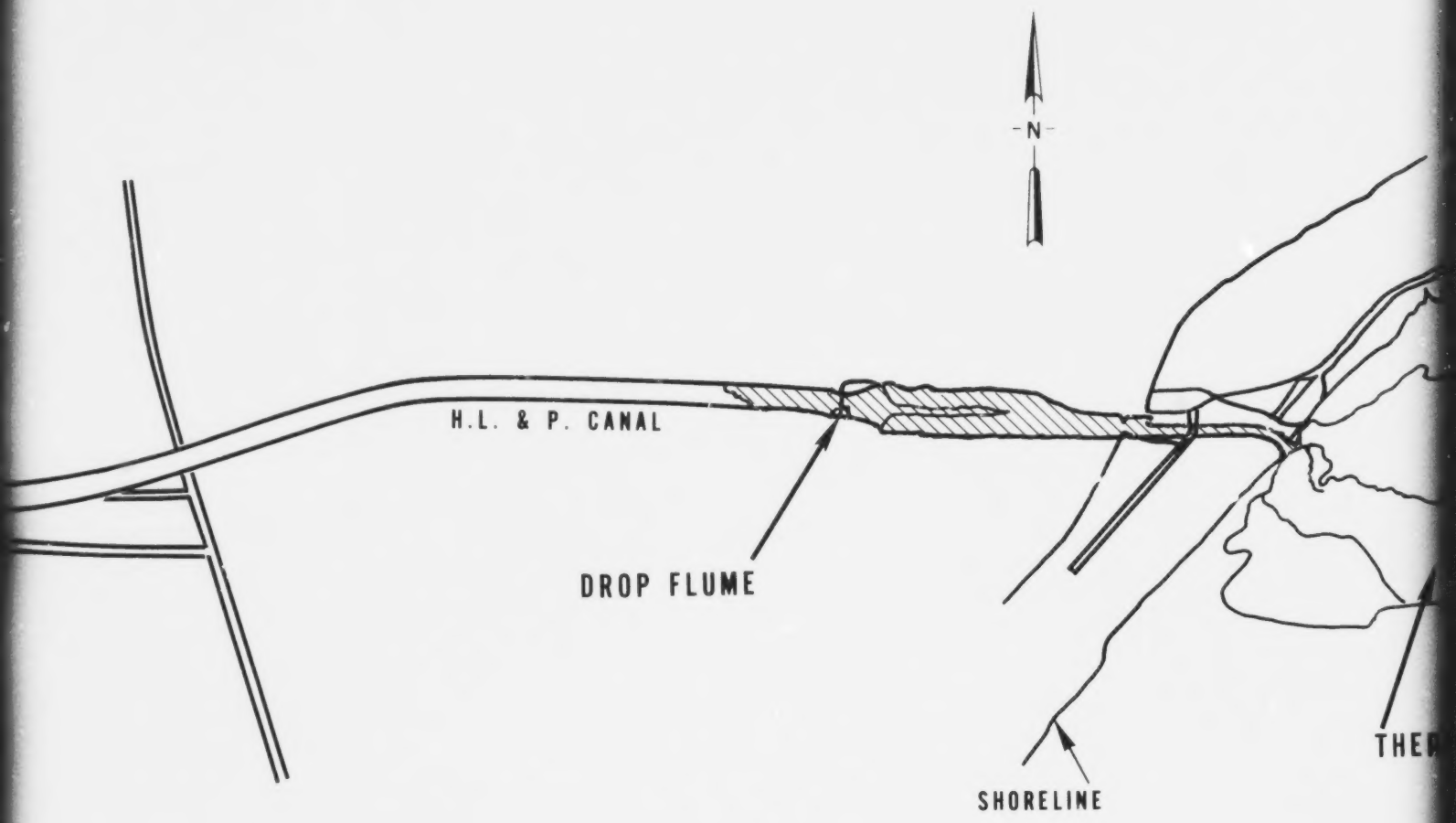


NOTE: CROSS-HATCHED AREAS IN CANAL INDICATE THE PRESENCE OF WARM WATER AT THE SURFACE

A



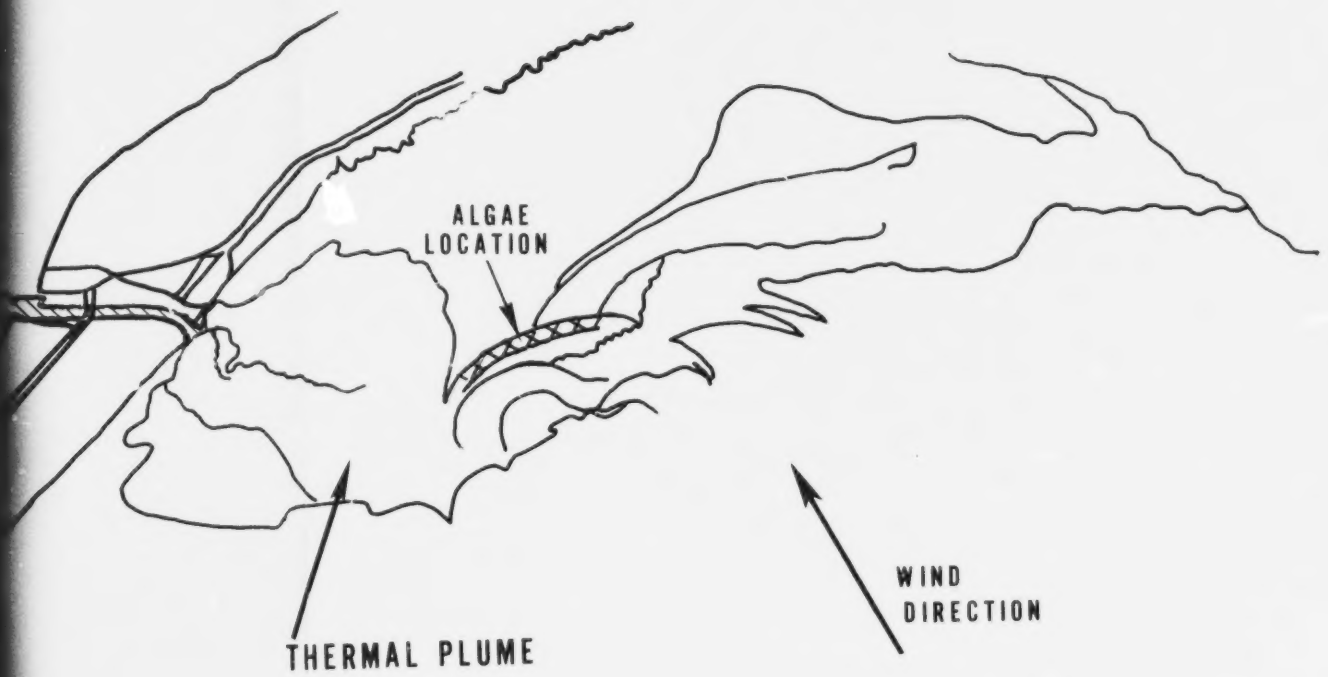
CROSS-HATCHED AREAS
IN CANAL INDICATE THE
PRESENCE OF WARM
WATER AT THE SURFACE



SCALE IS APPROXIMATELY 1:35,700.

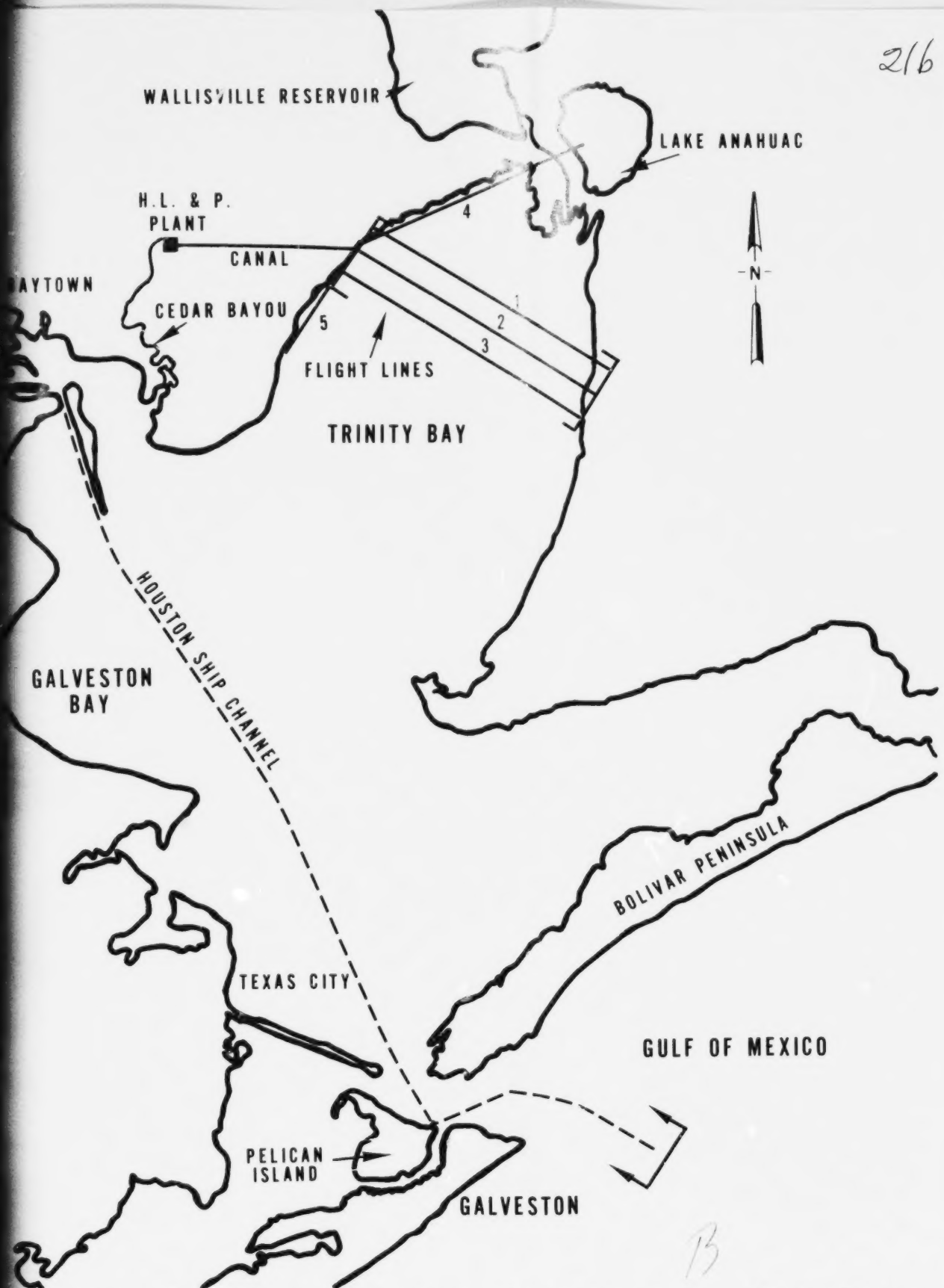
Figure 3 Thermal Imager

2/a



Thermal Imagery Houston Lighting and Power Company Canal

Figure 4 Houston Ship



Houston Ship Channel/Galveston Bay/Trinity Bay Flight Regime

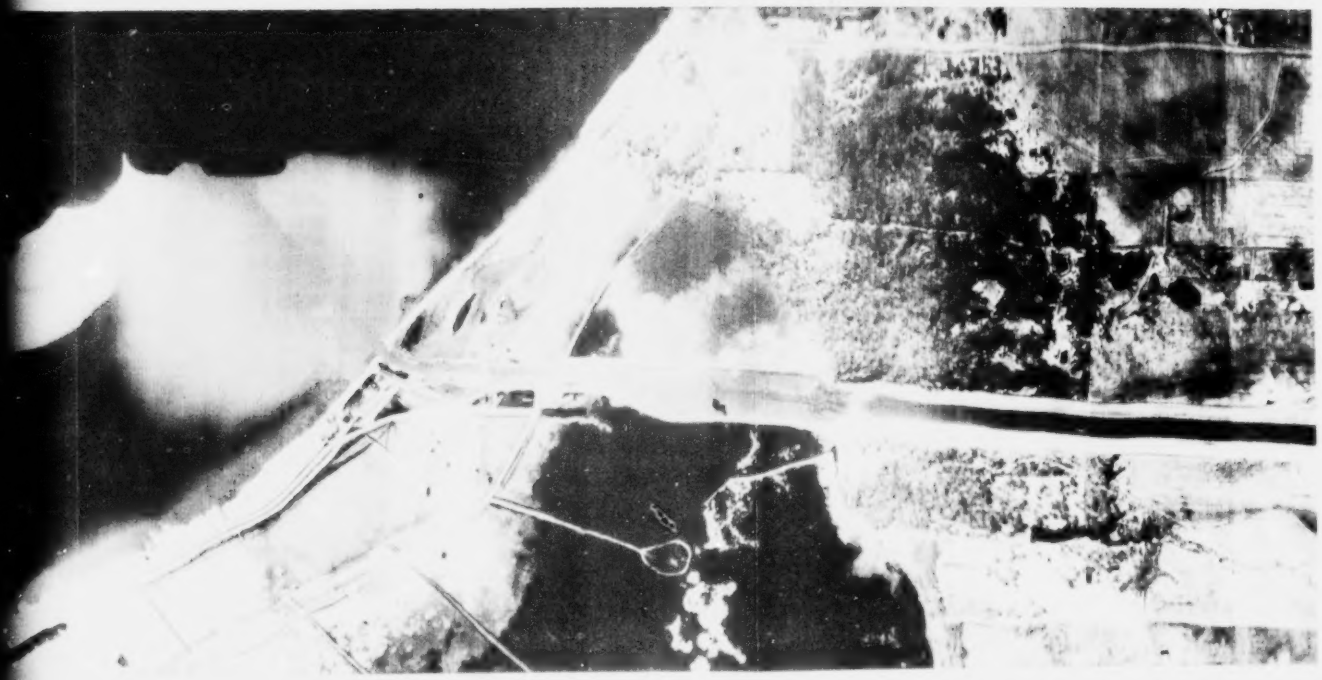
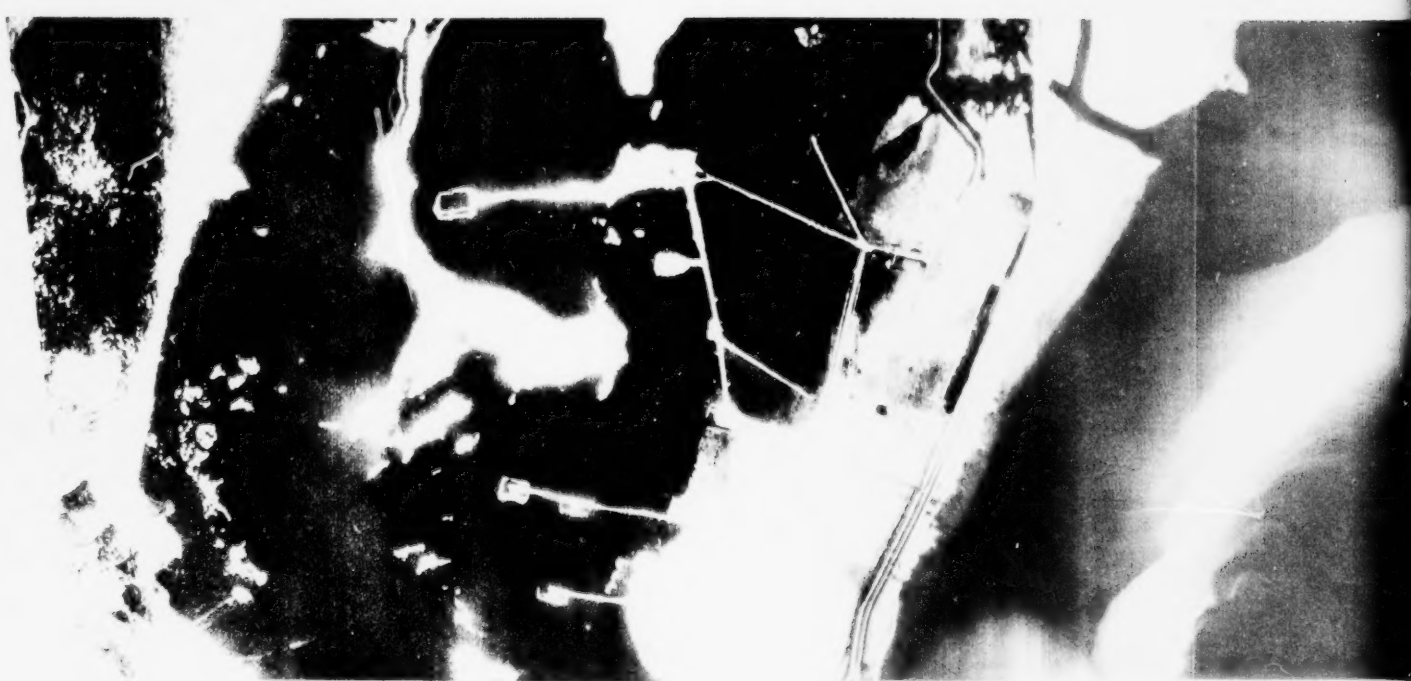
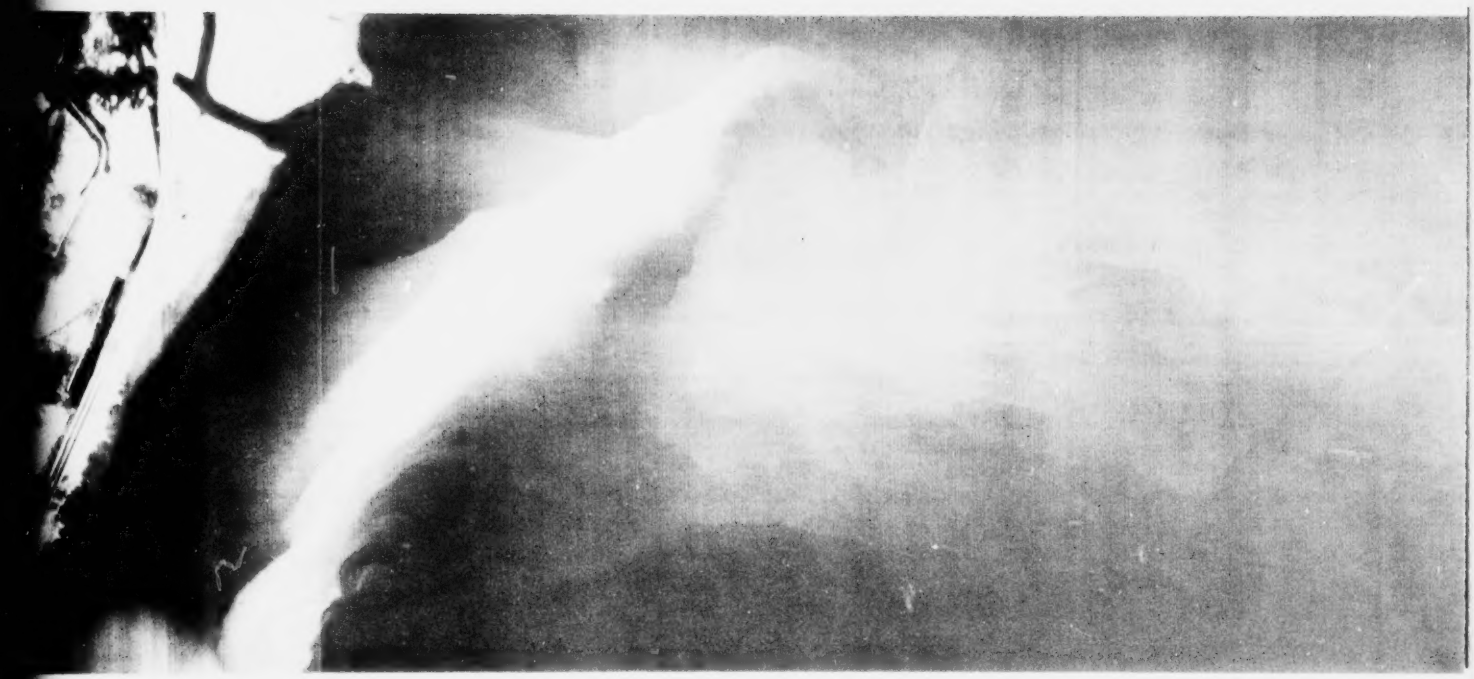
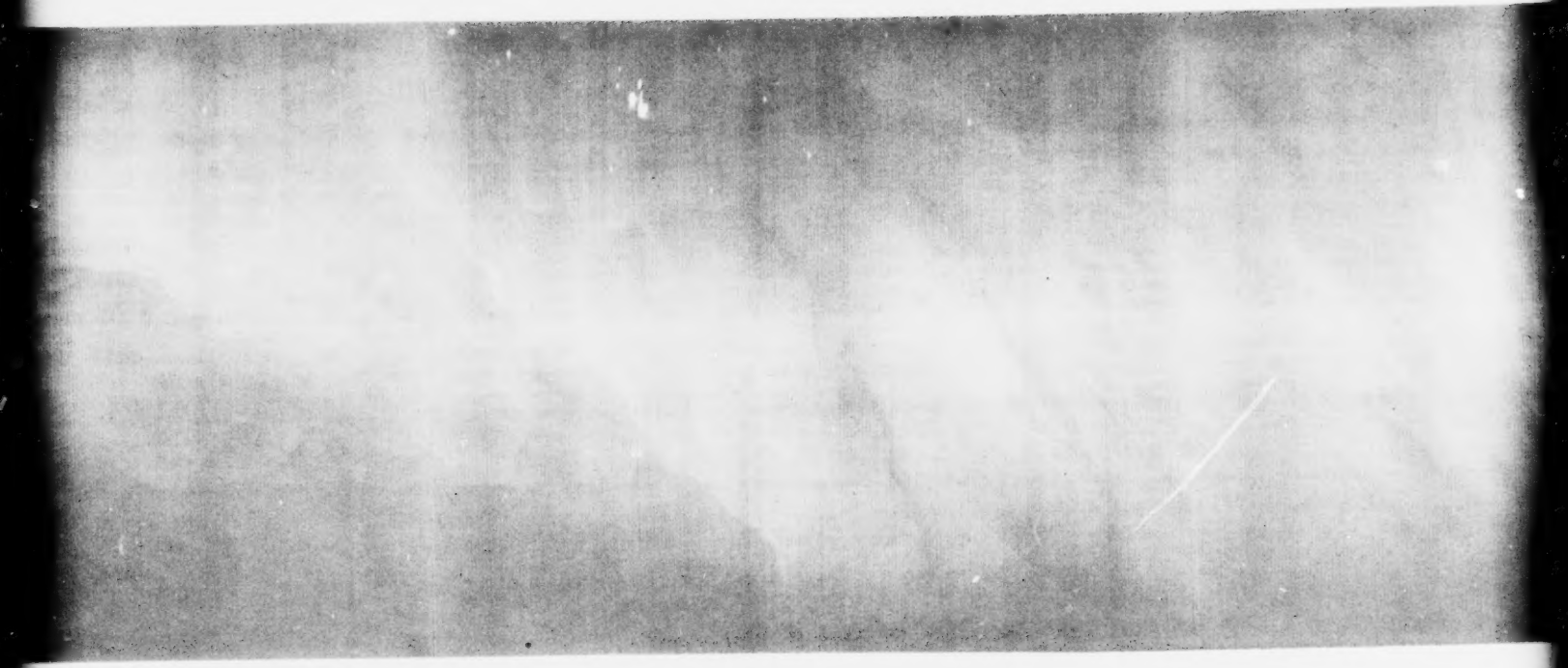
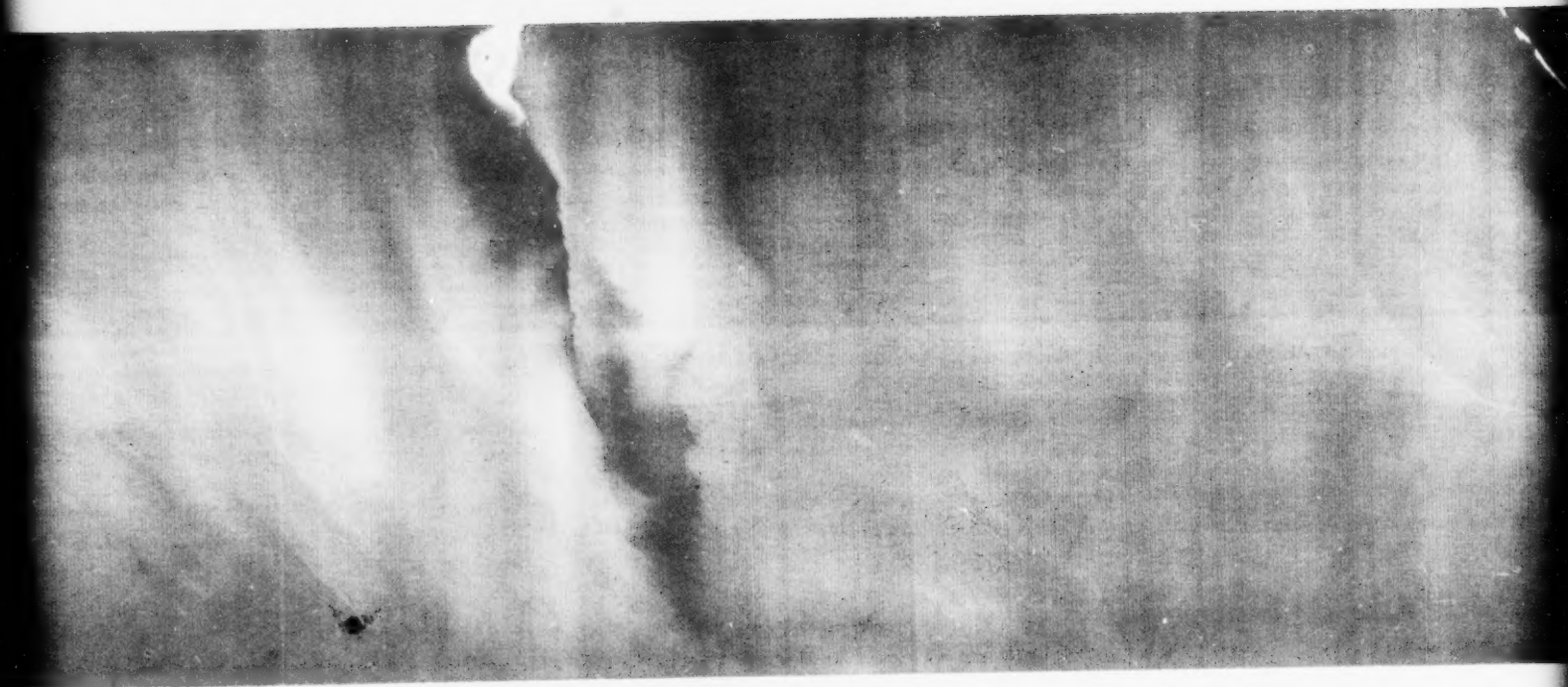


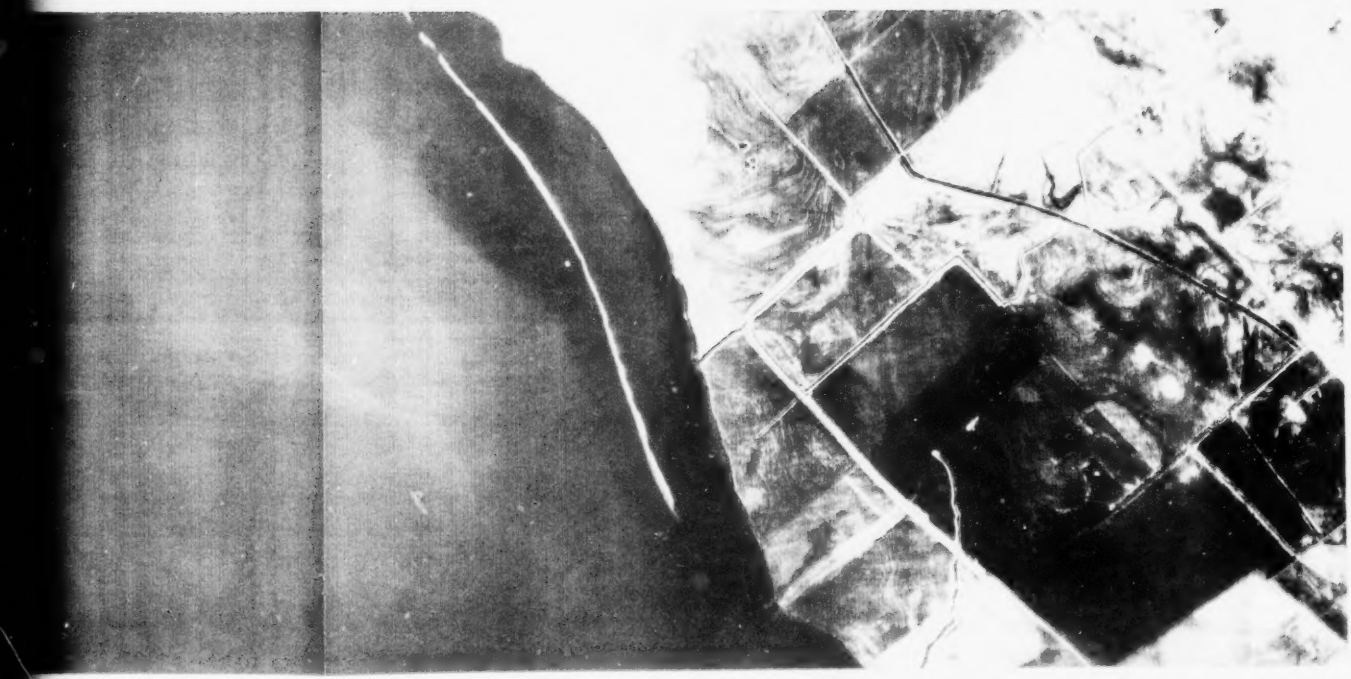
Figure 5





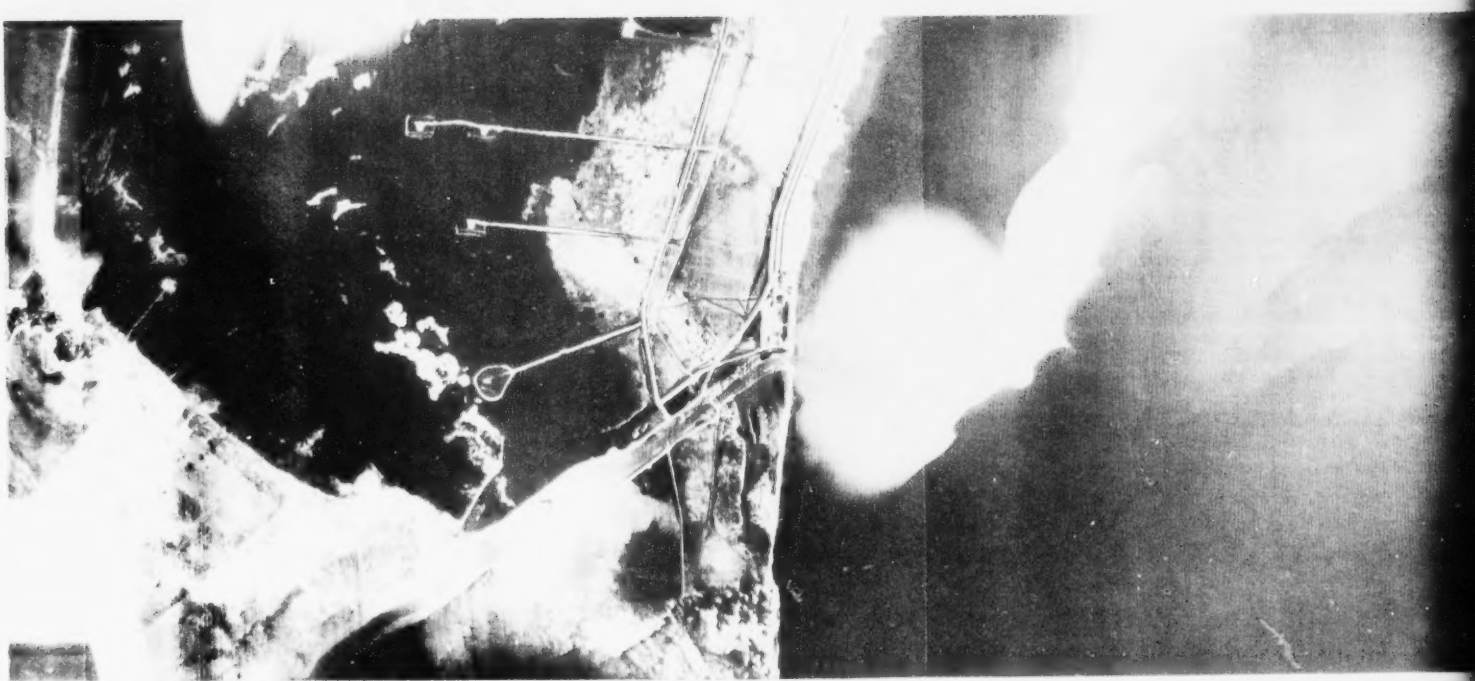






E

Figure 6



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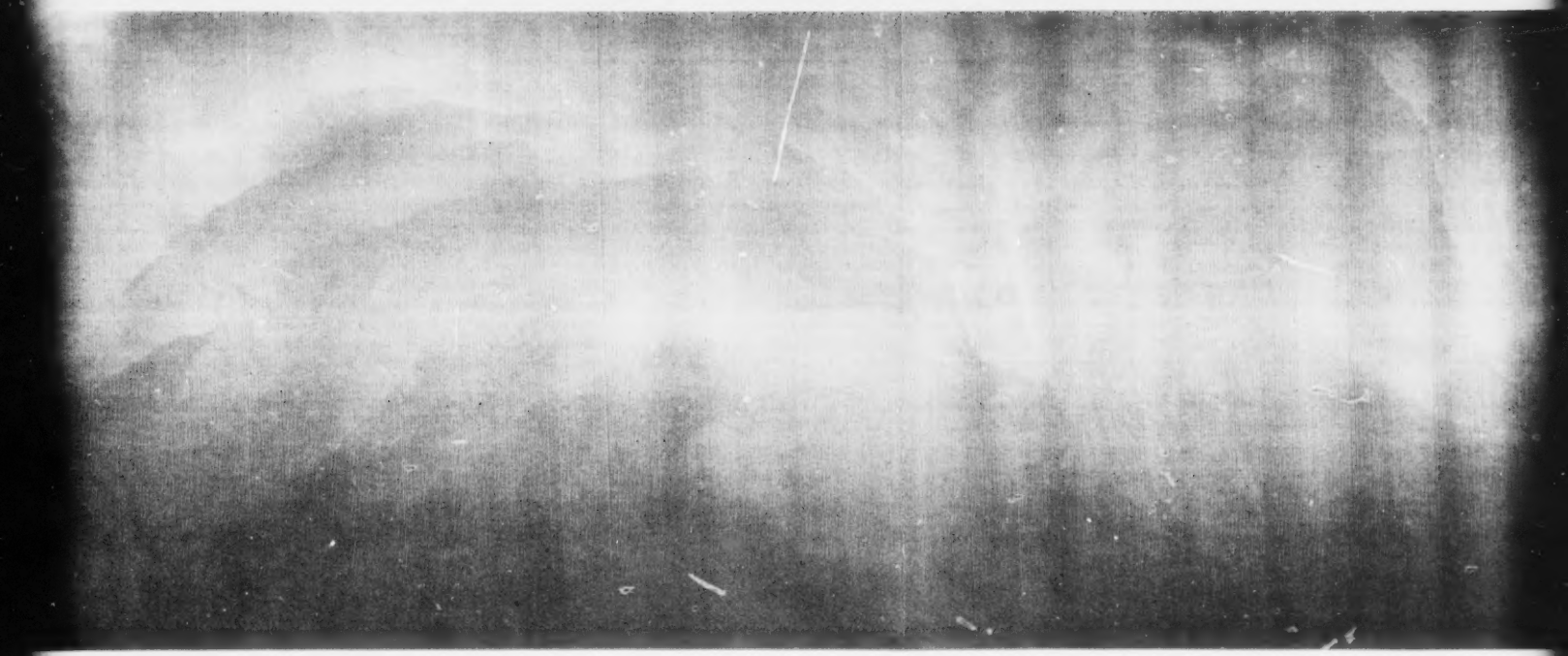

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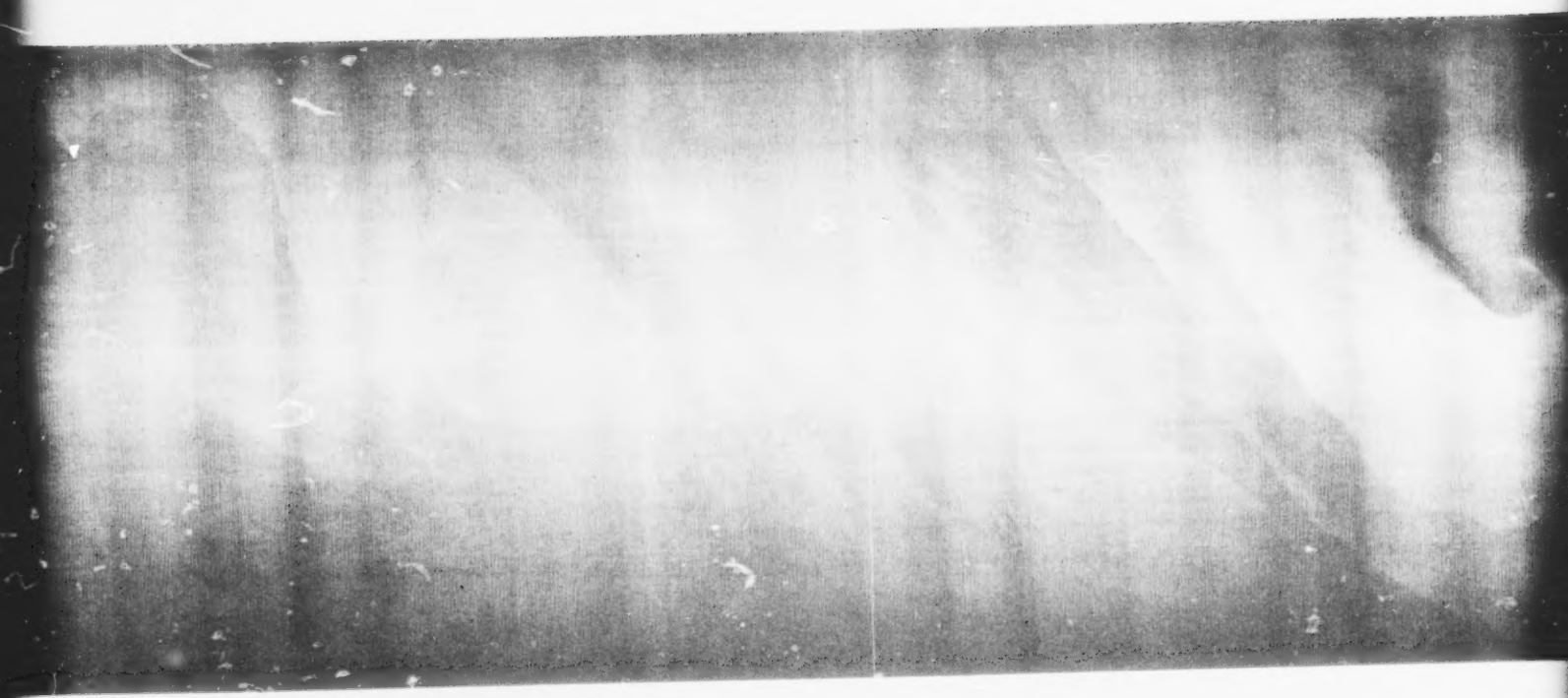

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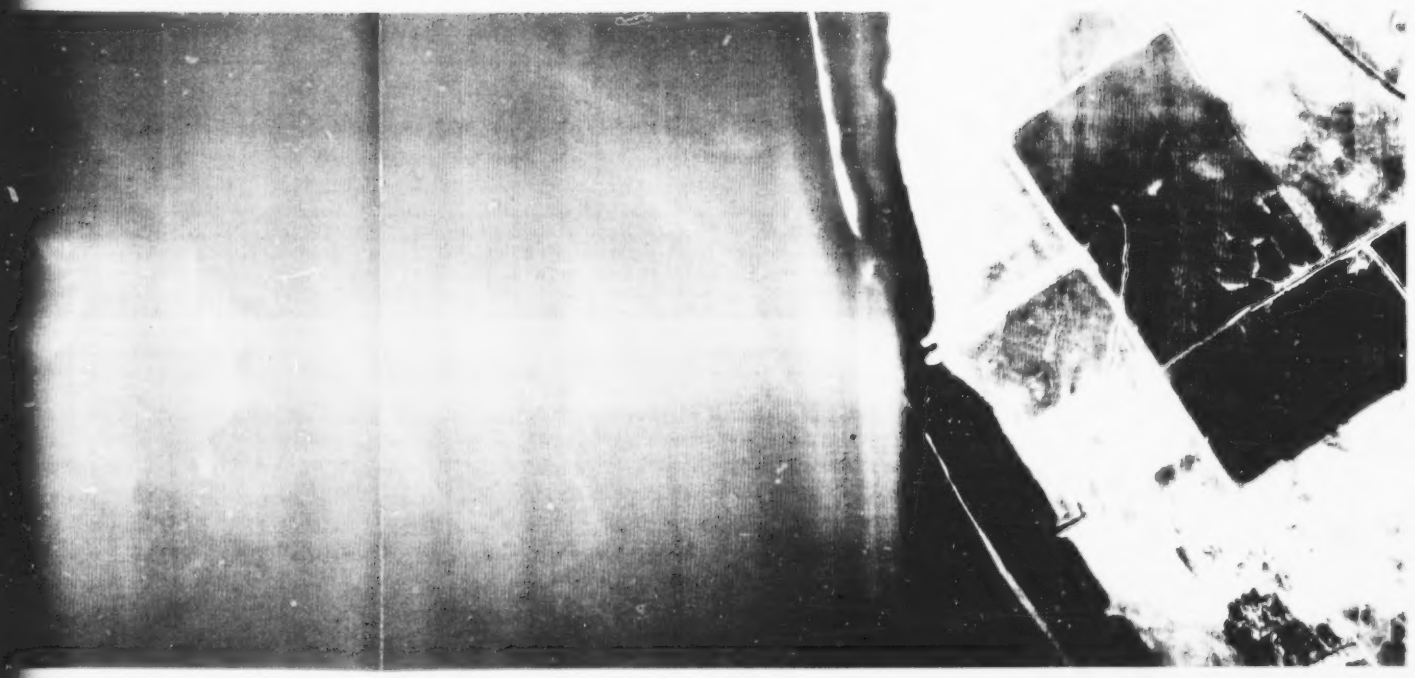
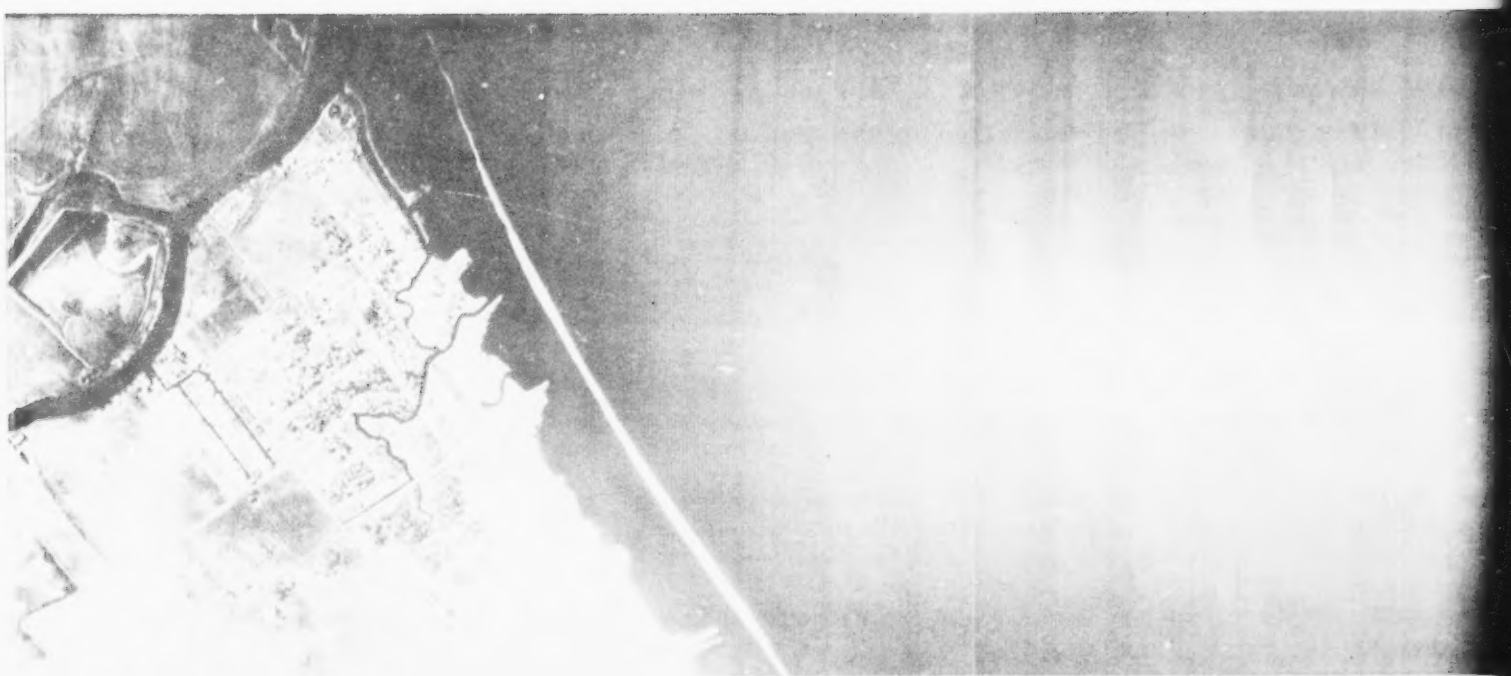


Figure 7



A

B

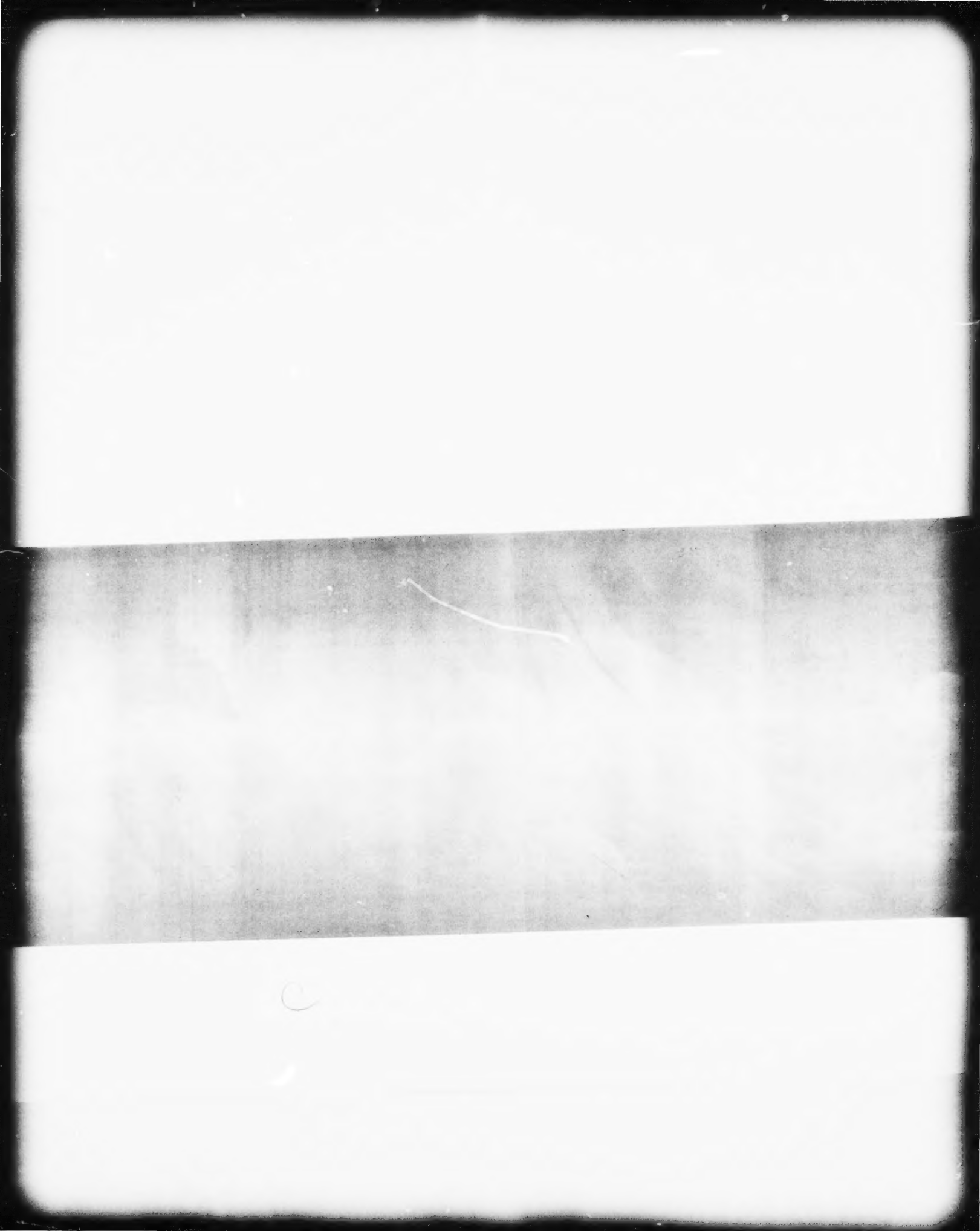
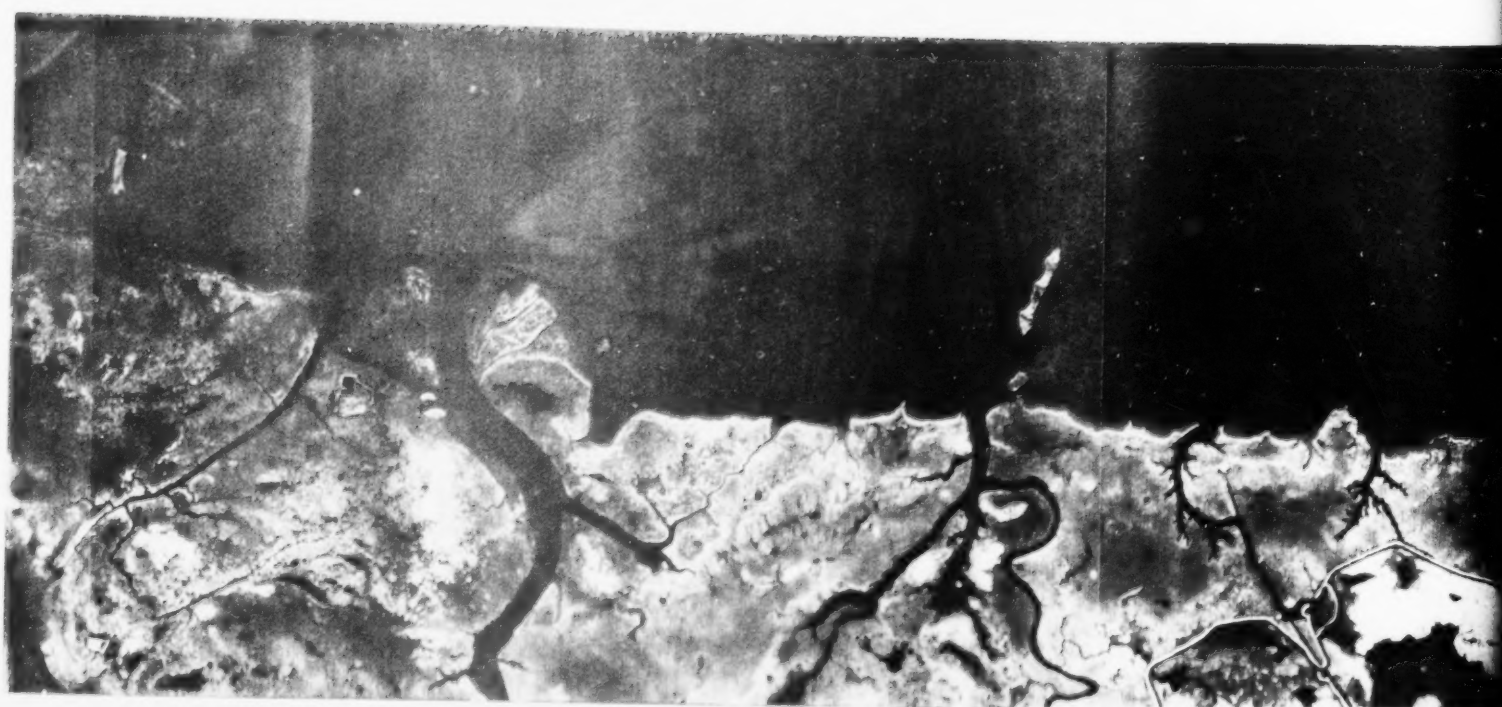
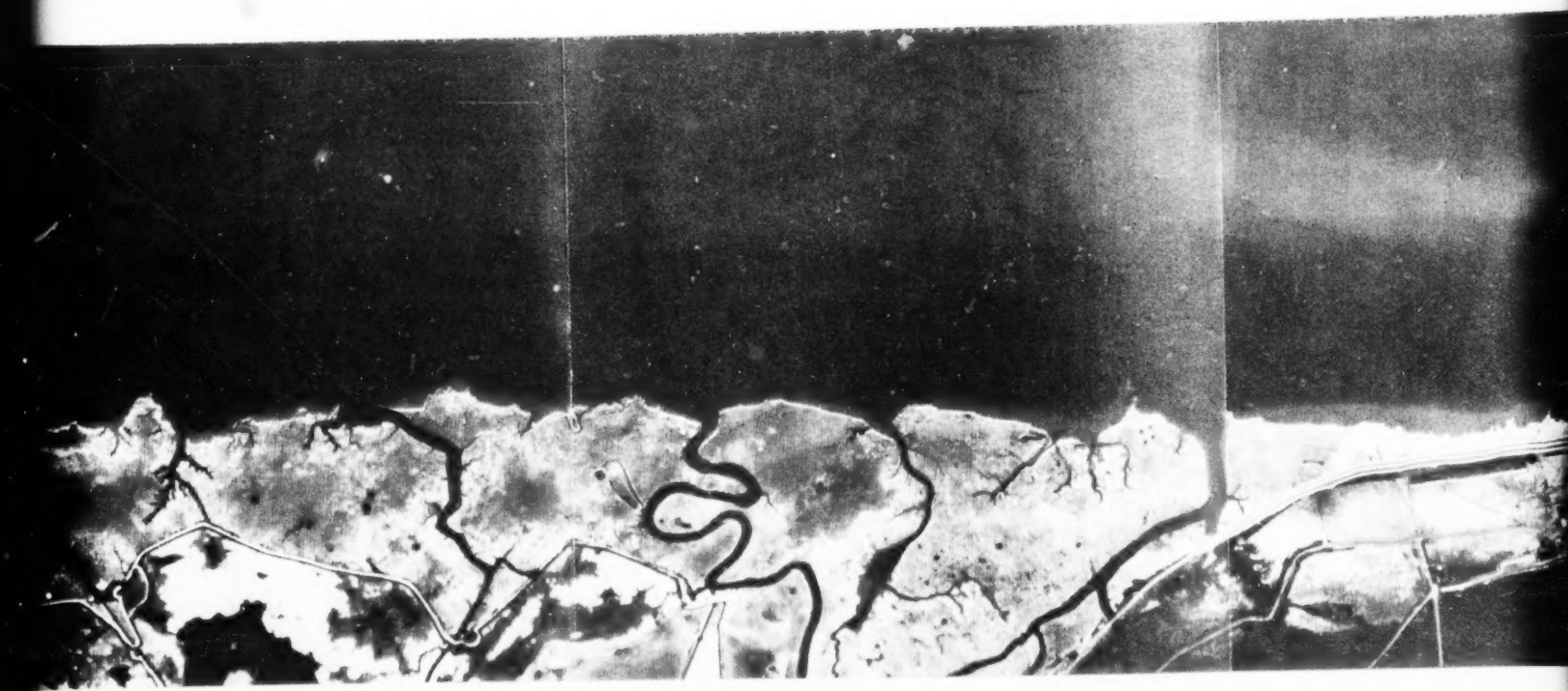


Figure 8





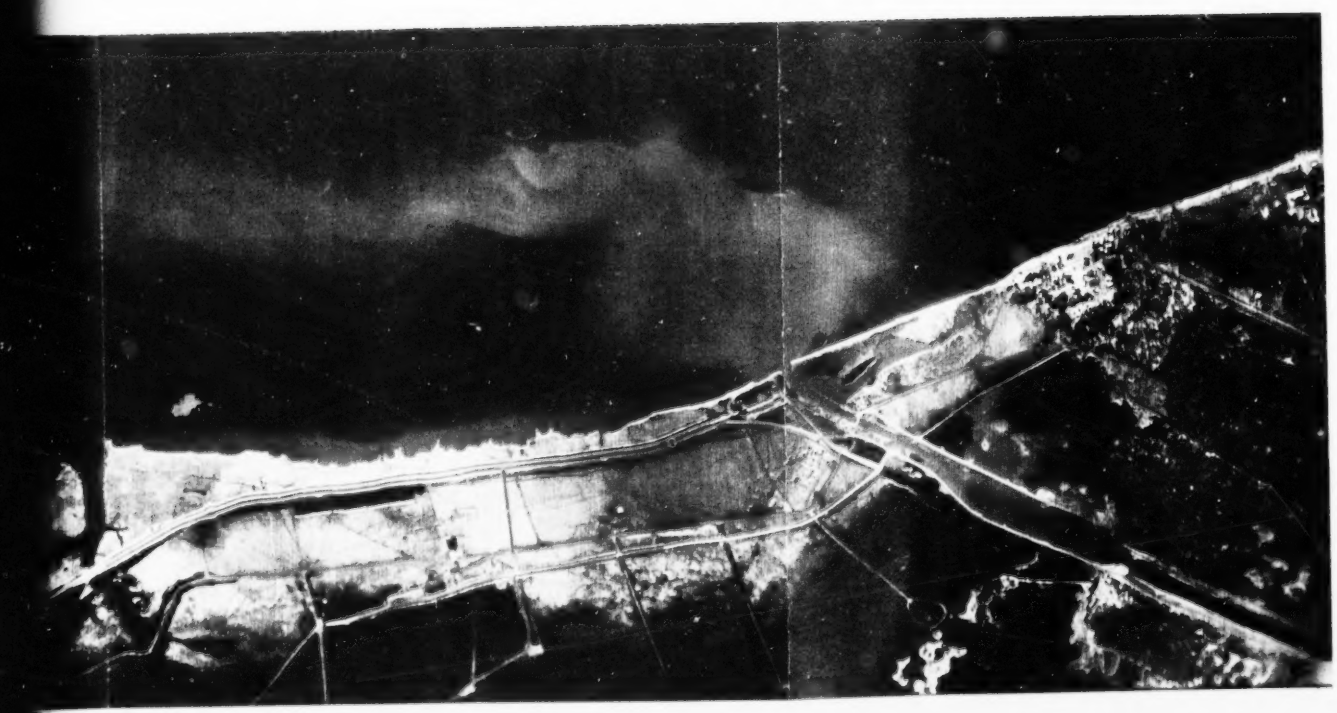
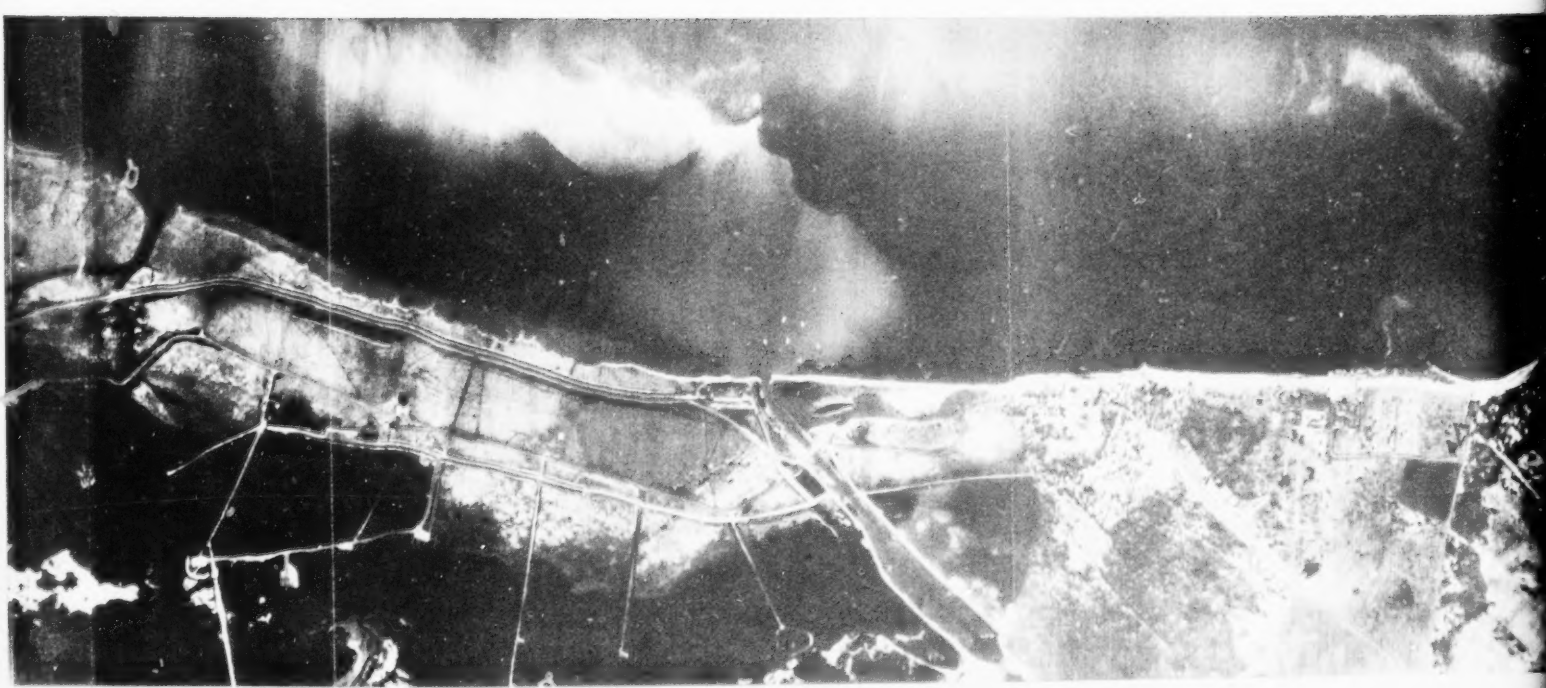
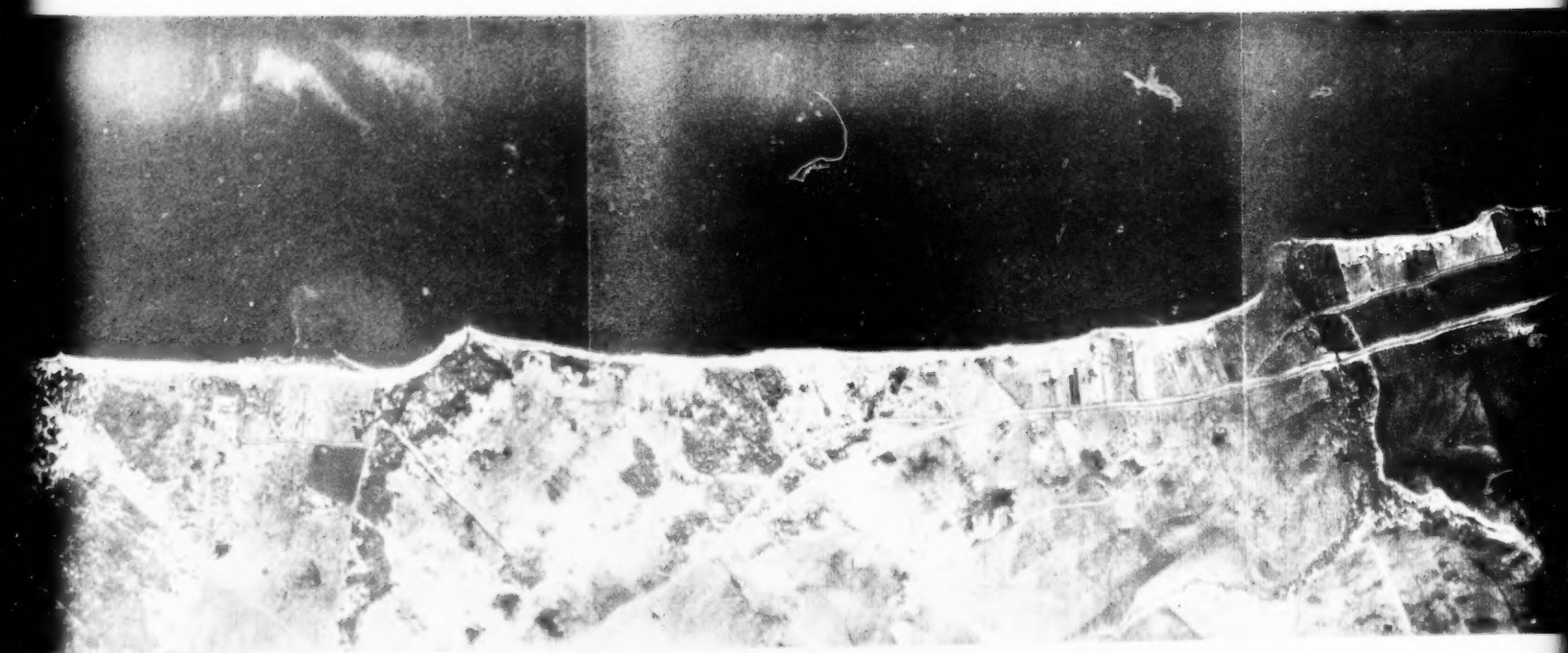


Figure 9





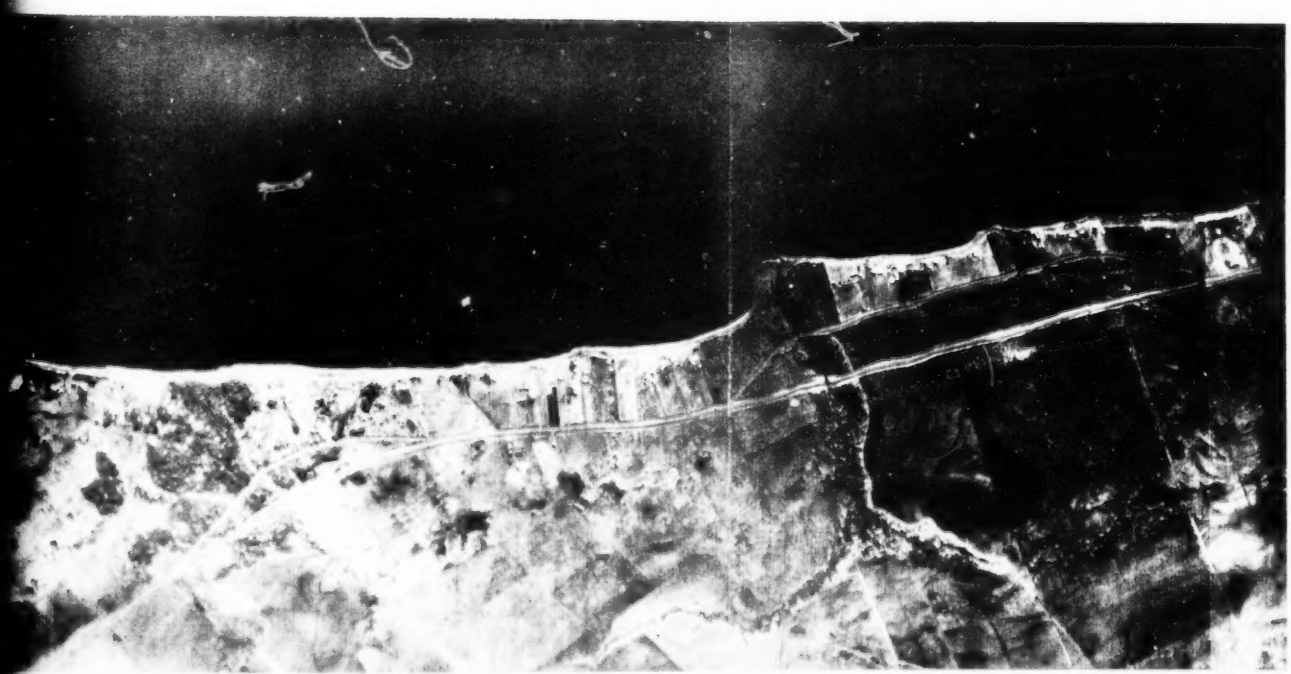


Figure 10

In order to document the dispersion patterns or characteristics of the aforementioned thermal plume, a specialized flight regime was utilized in obtaining the required IRLS imagery. The regime is shown in Figure 4. The imagery obtained is included as Figures 5 through 10. Figure 5 is a print of the imagery of the main body of the plume. Figures 6, 7 and 8 represent the imagery obtained from flight lines 1, 2, 3, respectively, in Figure 4. Figure 9 represents the imagery obtained from flight line 4, and Figure 10, that obtained from flight line 5. It was mentioned in the paragraph above that the thermal plume was drifting to the northeast as shown in Figure 3. By placing Figures 6, 7 and 8 side by side, forming a mosaic, it can easily be seen that the current patterns in Trinity Bay were in a clockwise spiral from the western shoreline across the bay to the eastern shoreline and then on into Galveston Bay.

The thermal plume, for the most part, had cooled to a temperature nearly equal to the receiving water ambient temperature at a point approximately 1 1/2 nautical miles northeast of the H. L. & P. canal discharge.

Within the area of the thermal plume the photographic imagery revealed the presence of an algae colony approximately 1/2 nautical mile due east of the canal discharge. This is indicated by the double cross-hatched area in Figure 3.

SUMMARY AND CONCLUSIONS

All industrial discharges present at the time of flight were recorded and identified to the extent possible. The presence of oil, during this mission, on the Channel waters was significantly less than that recorded during the July 1971 effort. Many industrial outfalls have been present during the total of four missions. As always, the discharges of

U.S. Plywood-Champion Paper Company, Crown Central Petroleum Corporation, Armco Steel Corporation, Ethyl Corporation, Southland Paper Company, Diamond Shamrock Company, and Rohm and Haas Company were present. The septic tendencies of the Channel waters had improved negligibly from last summer's flights.

The turbidity levels in the upper reaches of Galveston Bay were quite high at the time of flight. This is felt to have been partially caused by the southeasterly winds present at that time.

The behavior of the Houston Lighting and Power Company's thermal discharge was effectively documented, showing relative temperature levels and plume dispersion patterns.

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